

RESEARCH MEMORANDUM

PRELIMINARY FLIGHT INVESTIGATION OF THE MANEUVERING
ACCELERATIONS AND BUFFET BOUNDARY OF A 35°
SWEPT-WING AIRPLANE AT HIGH ALTITUDE
AND TRANSONIC SPEEDS

By George A. Rathert, Jr., Howard L. Ziff,
and George E. Cooper

Ames Aeronautical Laboratory
Moffett Field, Calif.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
February 21, 1951

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

PRELIMINARY FLIGHT INVESTIGATION OF THE MANEUVERING

ACCELERATIONS AND BUFFET BOUNDARY OF A 35°

SWEEP-WING AIRPLANE AT HIGH ALTITUDE

AND TRANSONIC SPEEDS

By George A. Rathert, Jr., Howard L. Ziff,
and George E. Cooper

SUMMARY

Results are presented from a series of exploratory flights on a 35° swept-wing airplane up to 1.09 Mach number to show the effects of compressibility presently imposing maneuvering limits. The buffet boundary is presented and a typical accelerated pull-up at 0.89 Mach number is shown in time-history form to illustrate the reversal in the variation of elevator-control force and position with normal acceleration which limited the maneuverability between 0.75 and 0.93 Mach numbers.

INTRODUCTION

The introduction into service of swept-wing airplanes capable of operating at high altitudes and transonic speeds has necessarily stimulated extensive flight investigations of both the dynamic- and static-stability and control characteristics under such conditions. Exploratory flights have been conducted by the NACA on a North American F-86A airplane at speeds up to a Mach number of 1.09 in order to identify various stability and control characteristics and determine what factors limit the maneuverability. The tests were made at altitudes of 48,000 to 35,000 feet to minimize aeroelastic effects and, if possible, isolate Mach number effects.

The purpose of this report is to present the flight limits explored to date and to summarize briefly the factors that presently impose maneuvering limits. To make this information available as rapidly as

possible it is presented with a minimum of analysis and is subject to modification as the research programs progress.

EQUIPMENT AND TESTS

The test airplane is a standard F-86A-5 (No. 48-291) with the addition of the external boom configurations shown in figure 1. The pertinent dimensions of the airplane are presented in table I, and a two-view drawing in figure 2. The airplane is equipped with the automatically opening leading-edge slats described in table I.

Standard NACA optical recording instruments, synchronized at 1/10-second intervals by a common timer, were used to determine the pressure altitude, Mach number, normal acceleration at the center of gravity, elevator position, and elevator stick force. The normal acceleration at the center of gravity also was measured with an unbonded-electrical-strain-gage-type transducer in conjunction with an oscillograph. The damping ratio of the transducer was 65 percent at a natural frequency of 80 cycles per second and room temperature, and that of the galvanometer in the oscillograph was 70 percent at a frequency of 95 cycles per second and room temperature. It is estimated that for the worst possible conditions of temperature of the transducer and oscillograph at the test altitude, the measured acceleration at a frequency of 50 cycles per second would differ from the true acceleration due to attenuation by no more than 25 percent. Acceleration measurements have not been corrected for attenuation. The normal acceleration is presented in this report in units of the acceleration due to gravity, g , 32.2 feet per second per second. The true Mach number was obtained from the nose-boom airspeed system (fig. 2), which was calibrated at transonic speeds by the NACA radar-phototheodolite method as described in reference 1.

Below a Mach number of 0.92 data were obtained in gradual pull-ups from level flight at an altitude of approximately 35,000 feet. At Mach numbers above 0.92 the airplane was dived to the desired Mach number and pulled up into the buffeting region using the elevators as the longitudinal control. The adjustable stabilizer was not used as a maneuvering control in these preliminary tests.

RESULTS AND DISCUSSION

Maneuvering Accelerations

The flight-test limits to date in terms of normal acceleration at the center of gravity and Mach number are presented in figure 3 in

comparison with boundaries defined by the maximum lift coefficient at low speeds and the structural limit. The maximum lift coefficient was determined from the flight-test points at 0.40 and 0.62 Mach numbers. The Mach number scale above 0.62 is divided into three sections labeled to show the effects of compressibility presently limiting the maximum maneuvering acceleration.

Up to a Mach number of 0.62 the maneuverability is limited only by a complete stall. The maximum lift coefficient remains substantially constant up to 0.62 Mach number. From 0.62 to 0.75 Mach number the stall is still the maneuvering limit, but the maximum acceleration attainable is reduced below that corresponding to low-speed maximum lift by the effect of compressibility on the airplane maximum lift coefficient.

Between 0.75 and 0.93 Mach number the maximum maneuvering acceleration is limited by erratic elevator-control forces, essentially a reversal of the variation of control force and position with normal acceleration which makes it difficult to attain or hold a specified acceleration above about 3g. This effect is a maneuvering limit primarily from the standpoint of avoiding "overshooting" or inadvertently pitching up to higher accelerations, since the reversal may occur quite abruptly in an accelerated maneuver. An example of a pitch-up anticipated and controlled by the pilot is presented in time-history form in figure 4. The continued increase in normal acceleration despite the reduction in both elevator-control force and elevator deflection is quite apparent. Three factors could contribute to the severity of the pitch-up in the type of maneuver shown in figure 4; stick-fixed longitudinal instability at high lift coefficients, a change in elevator effectiveness with decreasing Mach number, and a reduction in longitudinal stability with decreasing Mach number. Longitudinal instability at high lift coefficients has been noted on another swept-wing airplane, the Douglas D-558 phase II, as shown in reference 2.

From 0.93 to 1.09 Mach number, the highest speed reached, the normal acceleration was limited to the maximum attainable by use of the elevators alone at a stabilizer incidence of 0° . The reduction in the acceleration boundary at transonic speeds shown in figure 3, therefore, reflects a loss in elevator effectiveness or changing stability in this speed range and is not the limit of the maneuvering ability of the airplane, since higher accelerations could be obtained by use of the adjustable stabilizer. Most maneuvers at these speeds are accompanied by an appreciable reduction in Mach number, however, during which the stabilizer effectiveness or longitudinal trim may change in such a manner that the rate of stabilizer movement, 1.6° per second, would prove inadequate to retain control. Additional flight experience is considered necessary before tests are conducted beyond the maneuvering limits shown in figure 3.

Buffet Boundary

The buffeting region observed in the tests is shown in figure 3 and the buffet boundary is defined in terms of Mach number and airplane normal-force coefficient in figure 5. The buffeting characteristics are measured in terms of the oscillatory accelerations of the airplane structure as indicated by the response of the high-frequency normal accelerometer. For the purposes of this report, incipient buffeting is defined as a change in the amplitude of the record line which corresponds to 0.03g for the recording instrument used in these tests; therefore, the circular symbols shown in figure 5 indicate the first appearance of buffeting accelerations of the order of $\pm 0.03g$ at the center of gravity. A more detailed explanation of this definition and a comparison of these results with similar data from nine other aircraft and various buffeting criteria are presented in reference 3.

The dashed portion of the boundary in figure 5 above a Mach number of 0.93 is an extension where actual boundary points were not obtained. The square symbols indicate points of definite buffeting observed at normal-force coefficients as low as 0.081 above a Mach number of 0.97.

The test limits from figure 3 are also presented in figure 5 in terms of airplane normal-force coefficient. Within these flight limits explored to date, buffeting does not limit the operation of the airplane at an altitude of 35,000 feet, mainly because in the opinion of the pilot the buffeting intensities remain comparatively low with penetration beyond the buffet boundary. As noted on figure 3, the maximum intensity of buffeting at the center of gravity recorded thus far is $\pm 0.7g$ at a penetration of 2g or 0.5 normal force coefficient beyond the buffet boundary at 0.65 Mach number. The predominant frequency with $\pm 0.7g$ intensity was approximately 48 cycles per second. It was determined from ground shake tests that this frequency corresponded to the second overtone of symmetrical wing bending which excited the wing leading-edge slats through mass coupling.

Ames Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Moffett Field, Calif.

REFERENCES

1. Thompson, Jim Rogers, Bray, Richard S., and Cooper, George E.: Flight Calibration of Four Airspeed Systems on a Swept-Wing Airplane at Mach Numbers Up to 1.04 by the NACA Radar-Phototheodolite Method. NACA RM A50H24, 1950.
2. Sjoberg, S. A., and Champine, R. A.: Preliminary Flight Measurements of the Static Longitudinal Stability and Stalling Characteristics of the Douglas D-558-II Research Airplane (BuAero. No. 37974). NACA RM L9H31a, 1949.
3. Gadeberg, Burnett L., and Ziff, Howard L.: Flight-Determined Buffet Boundaries of Ten Airplanes and Comparisons with Five Buffeting Criteria. NACA RM A50I27, 1950.

TABLE I.— DESCRIPTION OF TEST AIRPLANE

Wing

Total wing area (including flaps, slats, and 49.92 sq ft covered by fuselage)	287.9 sq ft
Span	37.1 ft
Aspect ratio	4.79
Taper ratio	0.51
Mean aerodynamic chord (wing station 98.7 in.)	97.03 in.
Dihedral angle	3.0°
Sweepback of 0.25-chord line	35°14'
Sweepback of leading edge	37°44'
Aerodynamic and geometric twist	2.0°
Root airfoil section (normal to 0.25-chord line)	NACA 0012-64 (modified)
Tip airfoil section (normal to 0.25-chord line).	NACA 0011-64 (modified)
Leading-edge slats (one side only)	
Total area (projected into wing reference plane)	17.72 sq ft
Span	12.95 ft
Chord (constant)	1.37 ft

Horizontal tail

Total area (including 1.20 sq ft covered by vertical tail)	35.0 sq ft
Span	12.8 ft
Aspect ratio	4.65
Taper ratio	0.45
Dihedral angle	10.0°
Root chord (horizontal-tail station 0)	45.5 in.
Tip chord, equivalent (horizontal-tail station 76.68 in.)	20.9 in.
Mean aerodynamic chord (horizontal-tail station 33.54 in.)	34.7 in.
Sweepback of 0.25-chord line	34°35'
Airfoil section (parallel to center line).	NACA 0010-64
Maximum stabilizer deflection.	1° stabilizer nose up, 10° down

Elevator

Area (including tabs and excluding balance area forward of hinge line)	10.1 sq ft
Span, each	5.8 ft
Chord, inboard (equivalent horizontal-tail station 6.92 in.)	14.28 in.
Chord, outboard (theoretical, horizontal-tail station 76.18 in.)	6.92 in.
Maximum elevator deflection	35° up, 17.5° down
Boost	hydraulic

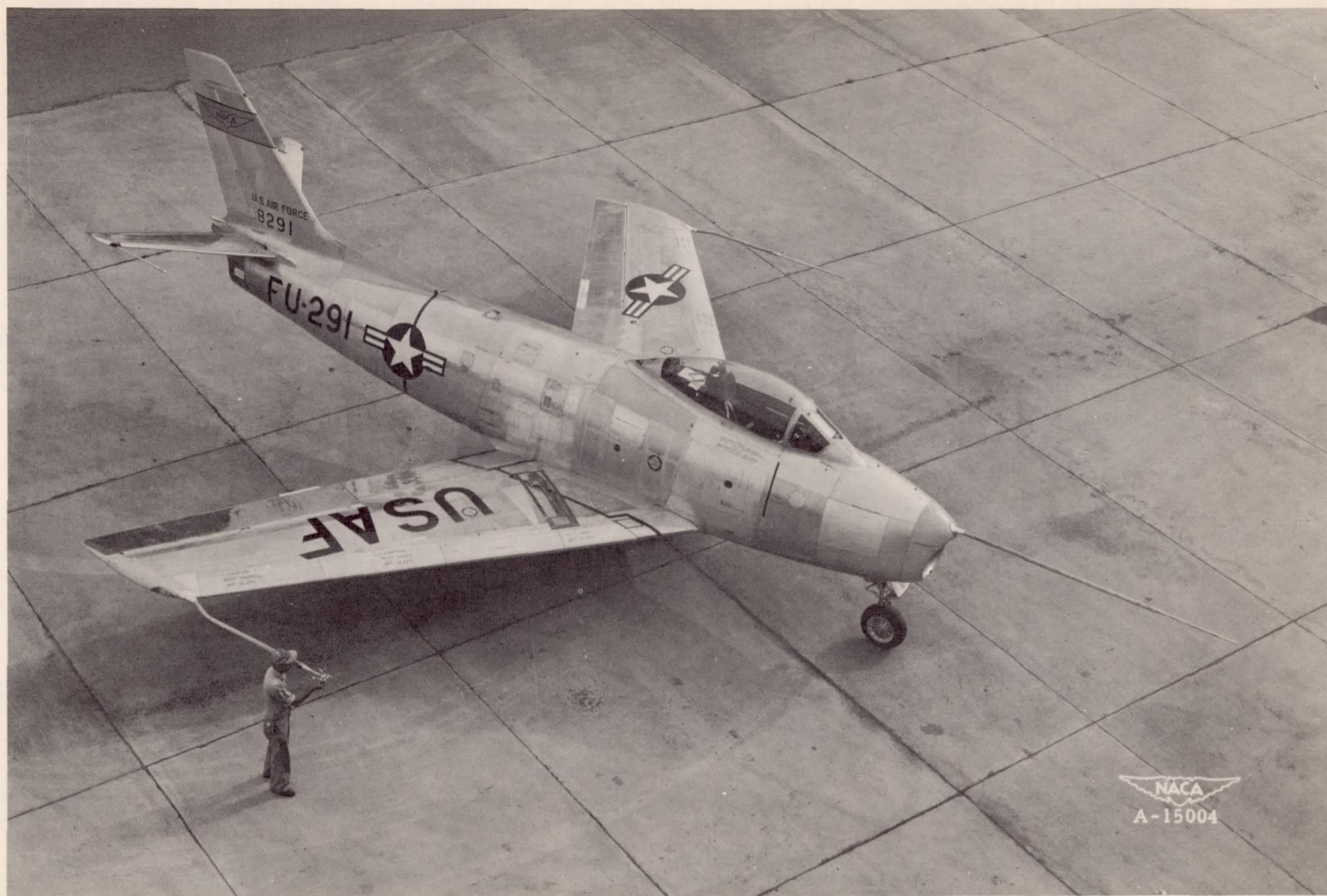
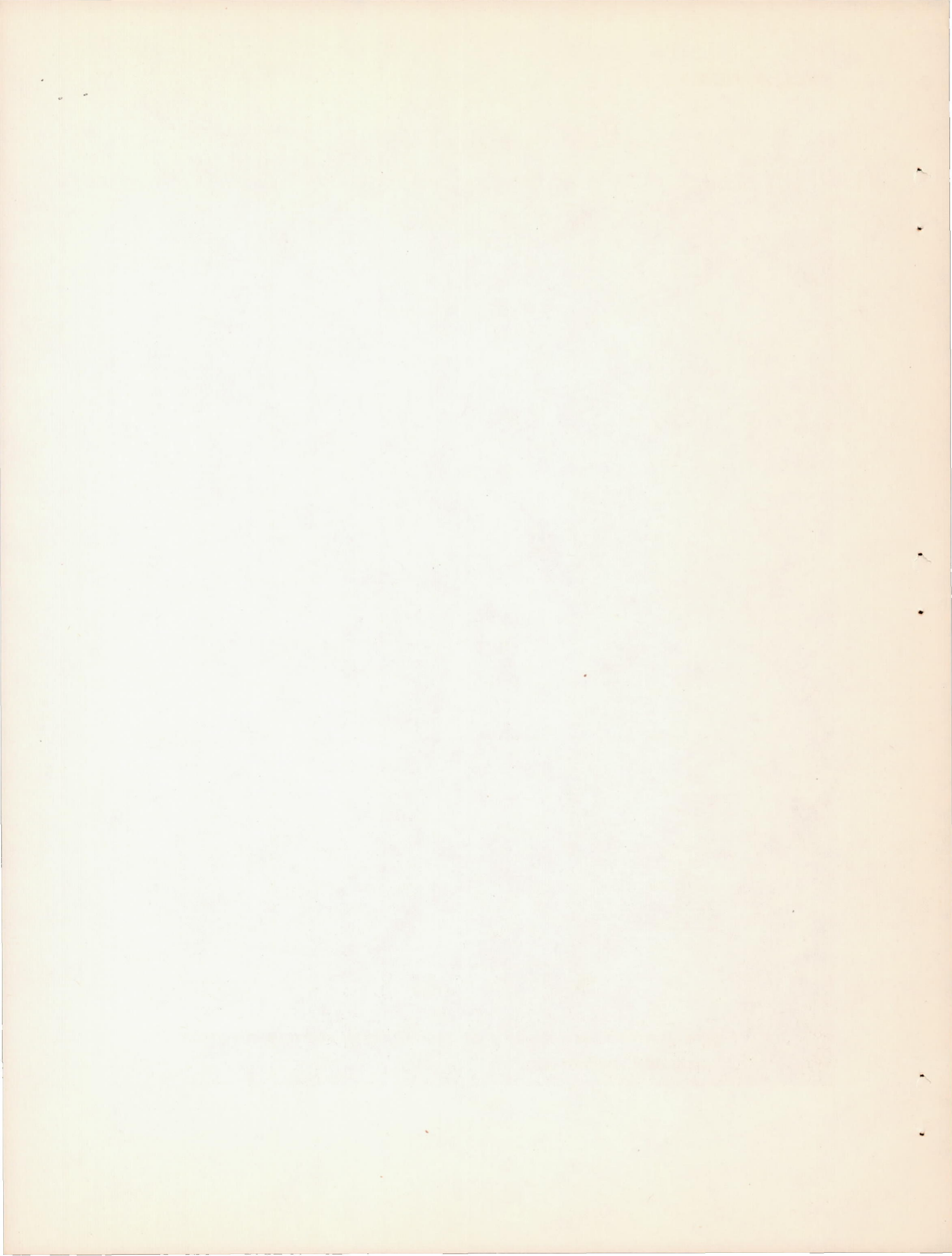


Figure 1.- Test airplane showing external boom configurations.



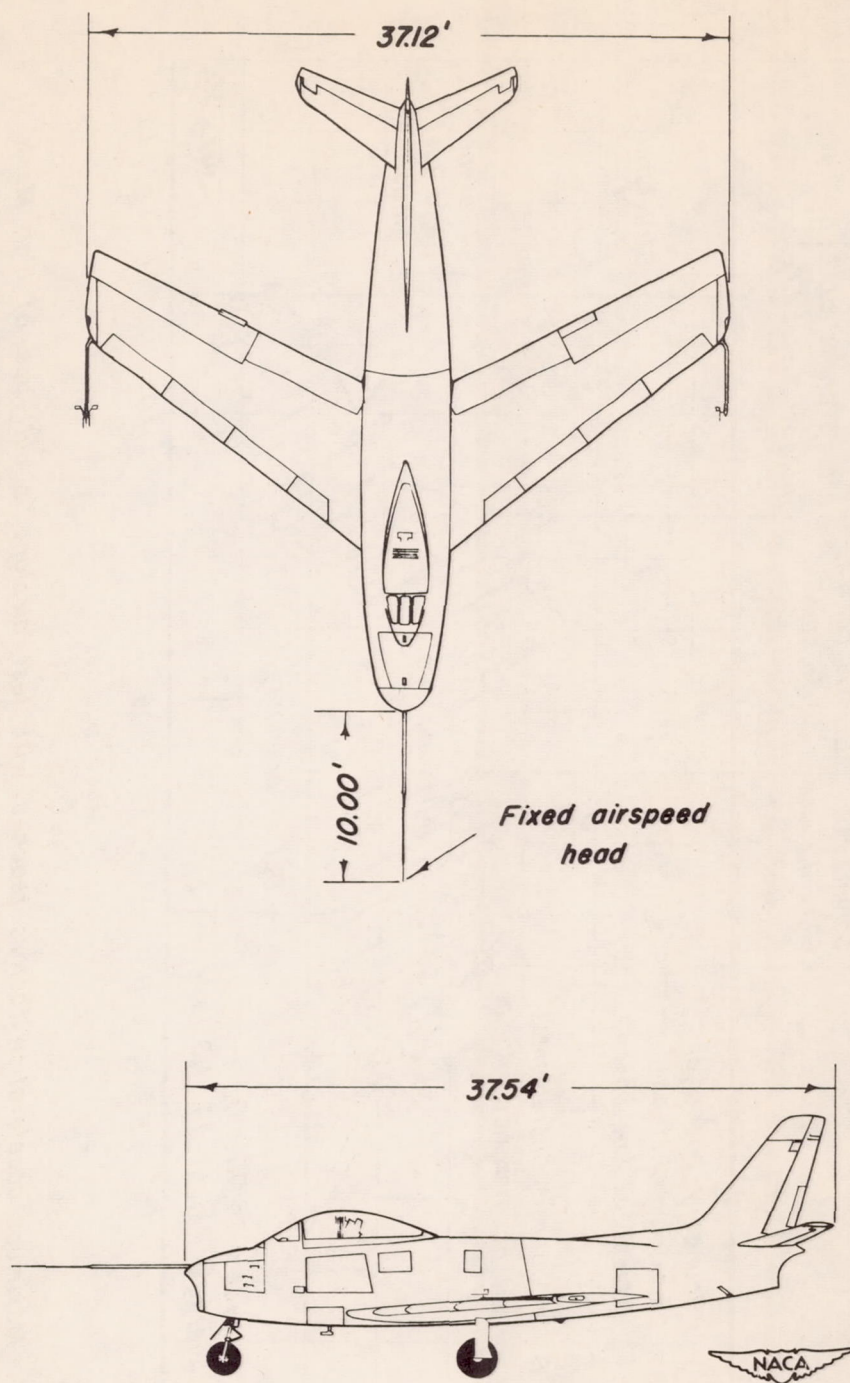


Figure 2.—Two-view drawing of test airplane showing research airspeed installation.

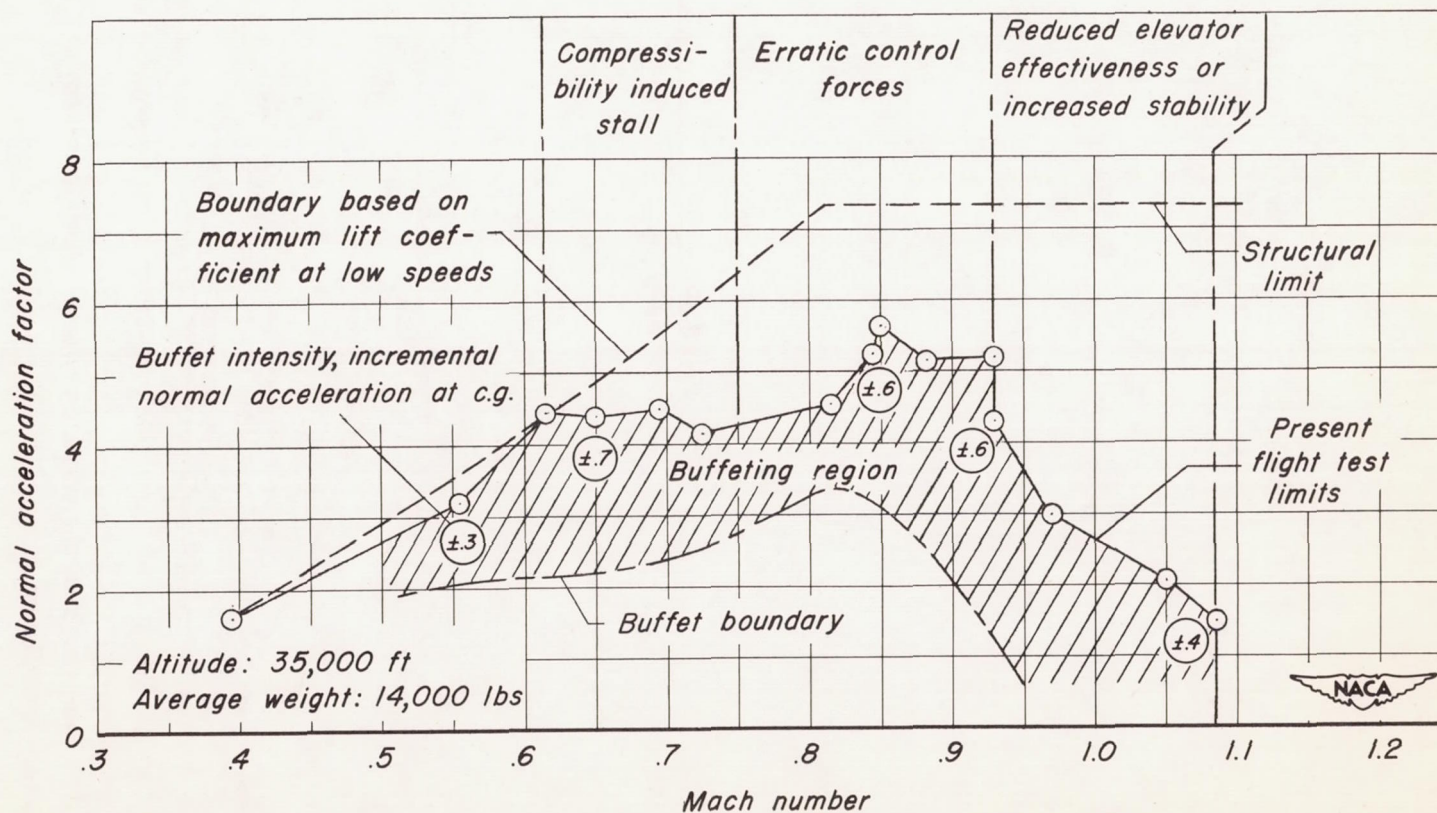


Figure 3.- Maximum acceleration factors reached with test airplane in pull-ups at high Mach numbers in comparison with boundaries based on the maximum lift coefficient at low speeds and the structural limit.

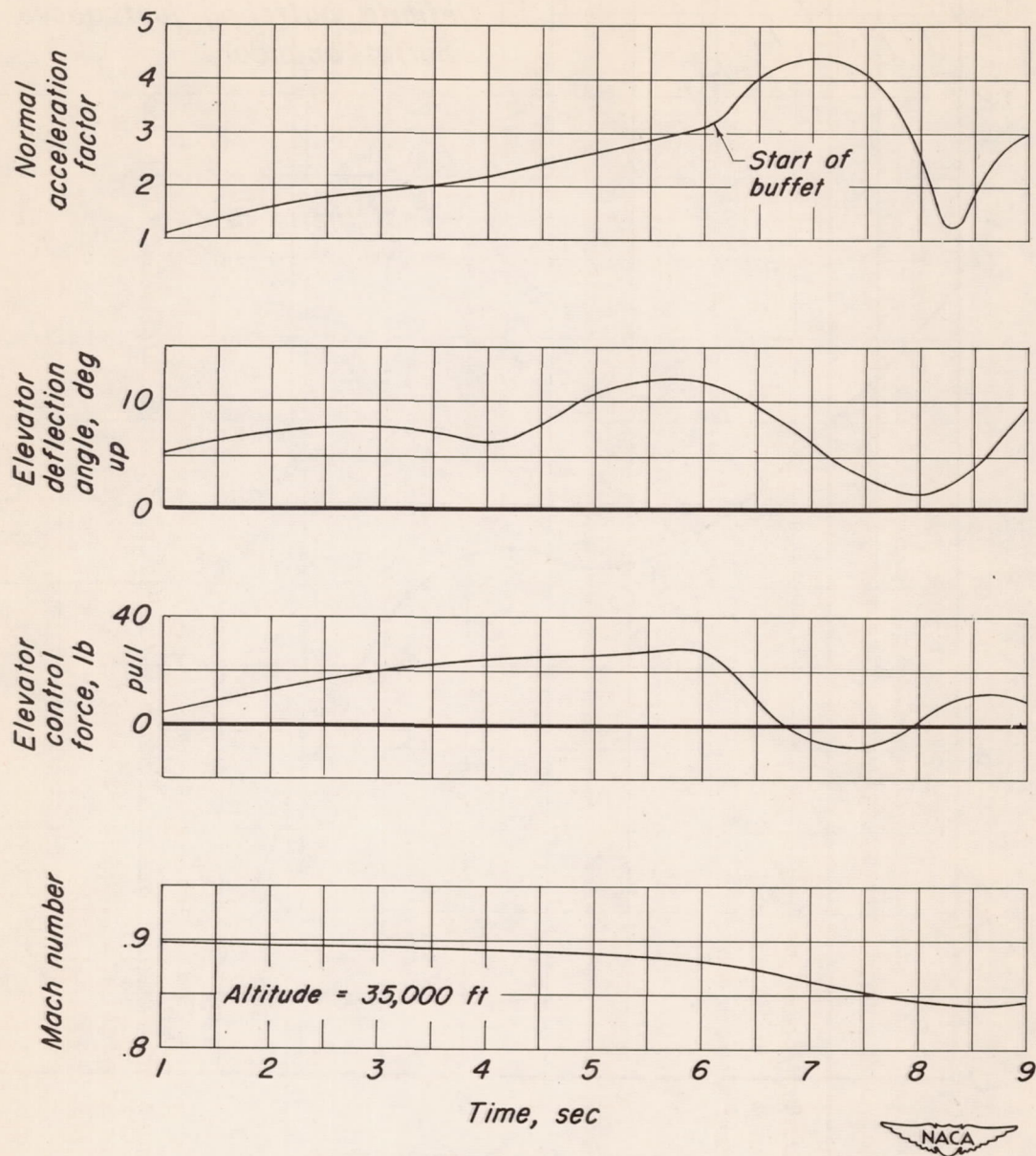


Figure 4.—Time history of pitch-up illustrating reversal of the variation of elevator control force and position with normal acceleration at the center of gravity.

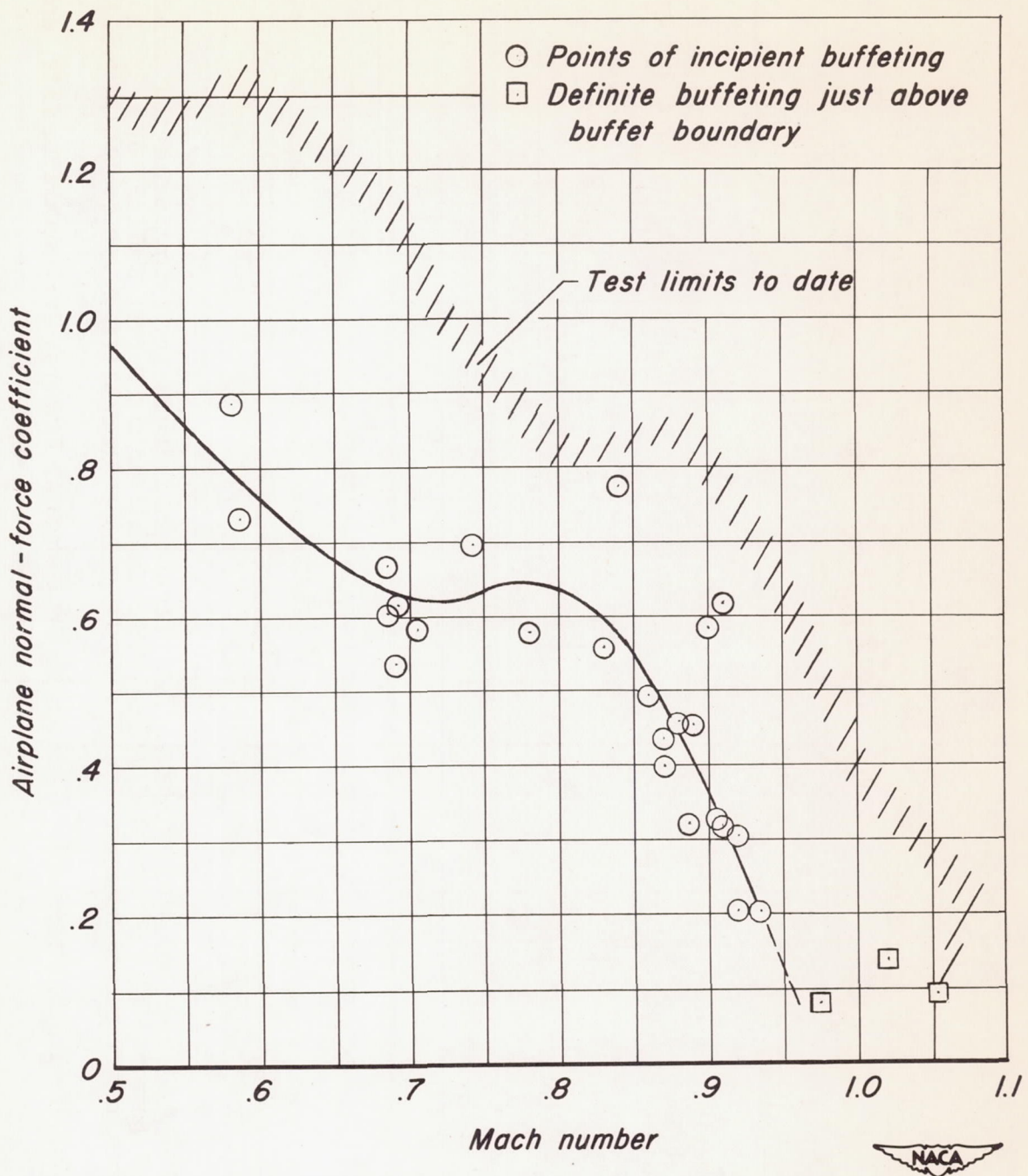


Figure 5.- The boundary defining the lower limits of buffeting on the test airplane in terms of Mach number and airplane normal-force coefficient.